Expert System for Lean Manufacturing at Tobacco Industry

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Abstract- Machine breakdown is inversely proportional to productivity. Breakdowns on critical machines disrupt the desired productivity significantly. To date, many procedures have been deployed to reduce the breakdown time. This paper deals with the application of expert system using the key principles of lean manufacturing. We developed systematic operating procedure to reduce the breakdown time of a specified machine in a cigarette manufacturing industry. In addition, this research explains to industries as how to get expert opinions irrespective of the expert's availability.

Keywords- Expert System, PW-2 Machine, Total Productivity Maintenance, Cigarette Manufacturing

I. INTRODUCTION

All manufacturing organizations are striving to eliminate different types of wastes. Waste minimization is mandatory to stay competitive in any market. Breakdown time that causes delay directly relates to the production capacity of a machine. However, eliminating the variation completely is a daunting task. Hence, to reduce the breakdown time a systematic approach is to be adopted to identify and remove the defects from machine. Availability of spare parts and tools, experts and maintenance procedures are mandatory. Principles of Total Productivity Maintenance (TPM) allow the operator of the machine to do routine maintenance. It is difficult for worker to remember each and every defect of the machine along with its root cause. Furthermore, experts are not always available. Artificial Intelligence (Expert System) helps them to generate a system of expert opinion dealing with machine malfunction and its root causes.

II. LITERATURE REVIEW

In global market intelligent production systems, maintenance techniques and trainings are essential to have a competitive system [i]. Systematic elimination or reduction of unneeded resources or waste is the key principle of lean philosophy [ii].

Knowledge Based Systems (KBS) make decision similar to those of human experts [iii]. It makes decision on the basis of observation and experience depending on how the expert opinions are entered into the expert database.

KBS or Expert System (ES) are the computer programs, which hold a set of rules for user to access the already fed data in specific domains. The main elements of a KBS are shown in Fig. 1. The user with the help of an interface asks queries from the inference engine. These queries could be in the form of push buttons, radio buttons, or even some alphanumeric entry. The knowledge database in a synchronize manner process a specific query. The knowledge base is developed through continuous expert inputs. The expert inputs are incorporated via knowledge acquisition module. The knowledge acquisition module includes different set of questions that are processed by different production rules in the inference engine. Once the production rules are applied to the specific query, the results could be displaced on the screen or in printed form.

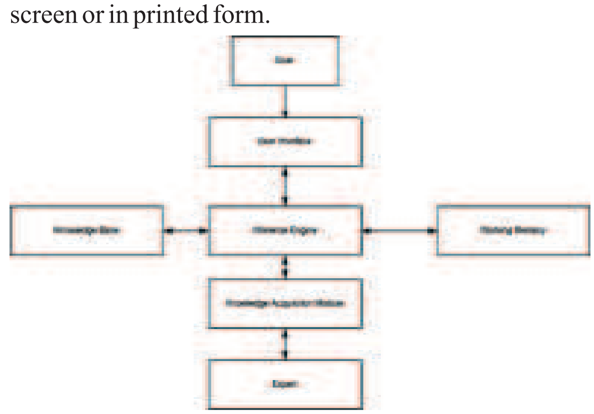

Fig. 1. Components of KBS/ES

Human experts are not always available. In addition, their consistency is doubtful and their reliability is less than hundred percent. They are subject to worldly matters. Expert System can be used everywhere at any time. Over a past couple of decades, expert system applications have been found in almost all the ways of life. The authors in [iv-xiv] have reviewed a number of KB systems applications. Table I summarizes the different applications of an expert system over a period of time.

TABLE I
EXPERT SYSTEM APPLICATIONS IN VARIOUS FIELDS
[IX-XXVI]

Application	Contributor (Year)
Job Shop Scheduling	Authors in [ii, x, xx]
Material Handling and Supplies	Authors in [ii, xv, xxvi]
Robots	Authors in [viii, xxiii]
Design of Flexible Manufacturing Systems	Authors in [ii, xxi]
CAD/CAM	Authors in [xxiv, ii, xvi]
Quality Control	Authors in [xix, xi, xii]
Facilities Layout	Authors in [xxv, ix]
Network Problems	Authors in [xiii, xviii]
Health Care	Authors in [xix, xvii]
Military	Authors in [xxii]
Urban Planning	Authors in [vi]

Different commercially available softwares are available to develop ES applications. These softwares have edge over the conventional programming tools. They have a number of facilities, which are lacking in the conventional programs such as ready written sub-routines, strong user interface, ease of integration with various modules and a number of databases etc. Application Manager (AM) is one of the available softwares. It is selected for the application under consideration.

III. Methodology

PW-2 machines are the technologically advanced cigarettes packing and wrapping machines. Millions cigarettes could be processed through it in an 8 hour shift. However, an ordinary breakdown degrades daily production considerably. A PW-2 machine has a built-in display screen. It shows the breakdown title but cannot guide the operator through its root causes for resolving. The operation either has to use his skills or has to engage the maintenance department. Total Productivity Maintenance (TPM) will boast worker ability to do the routine maintenance. An ES consisting of the breakdown along with its root causes can help the worker in effective and efficient problem resolving.

Technological and managerial advancement are very rapid in tobacco industry. Nothing could be proposed or inferred if a system is not studied thoroughly. For on-hand knowledge and experience of the current system, different parameters were identified. These parameters were related to different faults and maintenance procedures. The identification was carried out via literature review and manually recording the breakdowns occurred in many 8 hours long shifts.

With the help of manual sheets data is collected for a number of complete shifts. The data collected is analyzed through Pareto and Five why analysis. Based on these findings, information base is developed. Information base as discussed in Fig. 1 is responsible for keeping the database related to the identified parameters. Information base leads to the development of production rules. Testing phase of the expert system is initiated to remove bugs and errors. Fig. 2 gives a step-wise view of how this research progresses. This figure gives a pictorial view regarding data collection and analysis methods to be deployed for information base development.

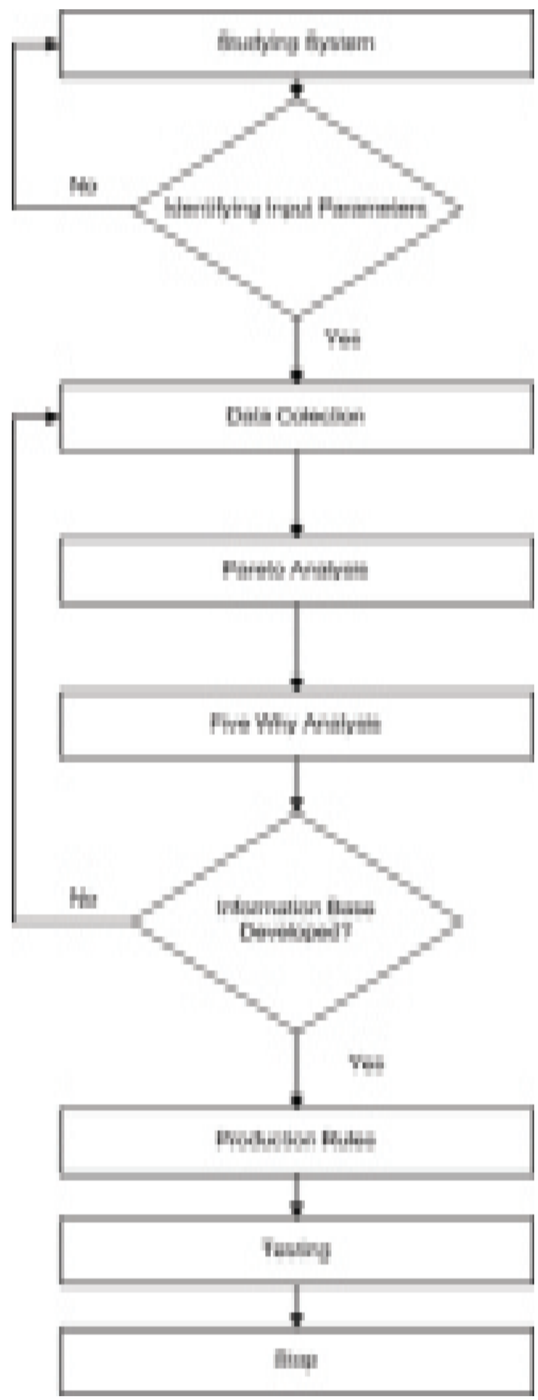

Fig. 2. Analysis Progress

Current system was studied for both operational and managerial perspective. It was unanimously decided to gather an eight hour-long shift data encompassing all types of breakdowns that occur. Manual sheets were initially used which were later transferred to an excel sheet. Table II depicts the type of data collected.

TABLE II
SAMPLE DATA FOR BREAKDOWN OF A SINGLE MACHINE

Sr. No	Run Time	Time (hours)		Detail Of Stoppages	Down time (hours)
		From	To		
1	0:05:00	6:00:00	6:05:00	No Cigarette from hopper detector	0:00:19
2	0:01:21	6:05:19	6:06:40	No Cigarette from hopper detector	0:00:25
3	0:04:04	6:07:05	6:11:09	Magomate problem	0:01:05
4	0:00:08	6:12:14	6:12:22	Blank jam in magazine	0:00:37
5	0:02:08	6:12:59	6:15:07	No Cigarette from hopper detector	0:00:45

For three weeks data is collected for the available three machines simultaneously. The collected data is analyzed with the help of Pareto analysis (i.e., 20% is responsible for 80%). The significant breakdowns both with respect to frequency and downtime are identified. The identified breakdowns are then shared with the maintenance experts to assess the breakdowns and generate data related to Fault Tree Analysis (FTA). Root cause identification is based on Five-Why technique. Fig. 3 illustrates how five why analysis is used for a specific fault. The same procedure was applied to all the identified faults.

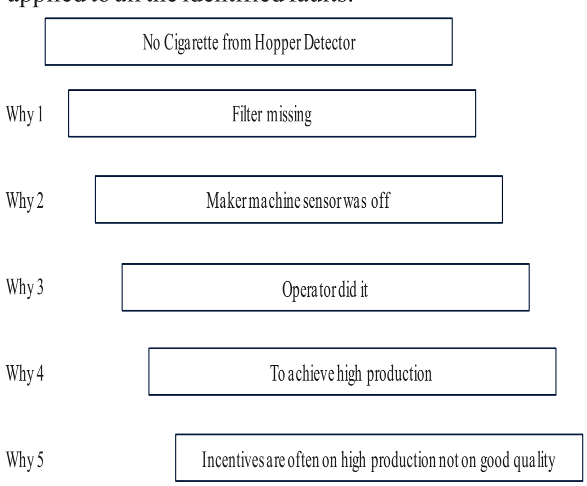

Fig. 3. Deploying Five Analysis

Fig. 3 depicts that “No cigarette from hopper detector” is the main problem. The Five Why analysis revealed that the root cause was related to organization policy and not with the maintenance procedures. The company was more interested in production than quality; hence, the operator would turn off the machine sensor for higher production.

A theme of information base is developed incorporating different production rules of the KBS. The developed ES is then tested on real production line and the improvement and suggestions are documented. Production rules for different breakdowns are developed using IF, AND, THEN, and OR rules. Forward chaining depth strategy is employed to execute rules. Rule for one of the breakdown “No cigarette from hopper detector” is shown below:

IF The breakdown occurred is “No Cigarette from hopper detector”

AND reason for it is cigarette jam

THEN check the incoming raw material
OR

IF The breakdown occurred is “No Cigarette from hopper detector”

AND its is due to loosen

THEN Check the machine

OR

IF The breakdown occurred is “No Cigarette from hopper detector”

AND the breakdown is due to filter missing

THEN the check the maker machine

OR

IF The breakdown occurred is “No Cigarette from hopper detector”

AND the breakdown is due to dust particles

THEN clean the machine

In this study, we developed a generic KBS, which can work for all available machines and equipment. The information base first input is related to the desired production and shift number. The desired production is usually on the higher side to motivate the operator. The first hour of the shift is categorized as cleaning and streamlining hour. The operator is asked to clean and check the inputs for machine carefully.

At the end of first hour actual hourly production is entered which is less than the desired production. The FTA screen of parent breakdown appears after entering the actual production. The operator then selects the occurred breakdown. The operator can access the root cause of the breakdown as shown in Fig. 4. At the end of second hour the operator again enter the actual hourly production and is able to access the FTA.

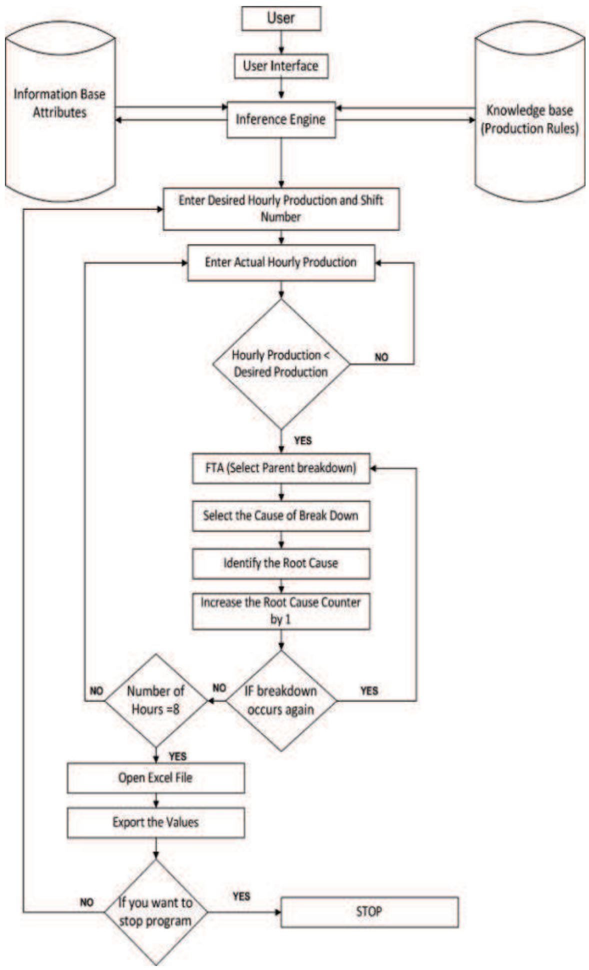

Fig. 4. Flow Chart of Expert System

A counter is attached to each of the parent breakdown and root cause. The counter increases every time the operator accesses a certain breakdown and its cause. At the end of shift all the production and counter values are exported to an excel sheet. The excel sheet is saved by a specific number with respect to date and shift. The saved excel sheet is used for upgrading the already developed information base and a printed version is kept in folder for management review. Fig. 4 gives an insight view of how the information base is utilized, improved and developed. Initially, such systems are run and tested for a warm up period. New problems and new issues may arise, which are then fed into the expert system in coordination with the respective expert.

The expert system developed was verified by the academic and industrial experts and was then validated on twenty one (seven on each machine) readings as shown in Table III.

TABLE III
SUMMARIZING MACHINE BREAKDOWNS

Sr. No	M/c No	Downtime/ Shift (Hrs: Min: Sec)	Remarks
1	1	02:10:03	Database updated and root causes verified
2	2	01:49:34	Database updated and root causes verified
3	3	01:53:43	Database updated and root causes verified
4	1	01:59:50	Database updated and root causes verified
5	2	01:56:32	Database updated and root causes verified
6	3	01:48:48	Database updated and root causes verified
7	1	01:56:12	Database updated and root causes verified
8	2	02:01:48	Database updated and root causes verified
9	3	01:45:09	Database updated and root causes verified
10	1	01:51:11	Maintenance Performed (Warm up run)
11	2	01:43:35	Maintenance Performed (Warm up run)
12	3	01:49:57	Maintenance Performed (Warm up run)
13	1	01:48:19	Maintenance Performed through ES
14	2	01:53:29	Maintenance Performed through ES
15	3	01:42:53	Maintenance Performed through ES
16	1	01:18:30	Maintenance Performed through ES
17	2	01:23:45	Maintenance Performed through ES
18	3	01:19:23	Maintenance Performed through ES
19	1	01:12:13	Maintenance Performed through ES
20	2	01:09:09	Maintenance Performed through ES
21	3	01:03:10	Maintenance Performed through ES

V. Results and Discussion

The downtime is significantly reduced after eliminating the root causes using the expert system. The Bar chart in Fig. 5 shows the reduction in downtime for the first, second and third collected data. The numbers shown in the bars are in the hours/minutes/seconds format. The reduction is approximately 30 minutes in each shift.

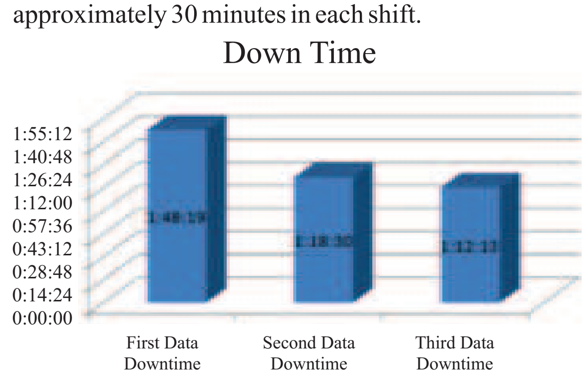

Fig. 1. Downtime of a single PW-2 Machines

After implementing the expert system, approximately 30 minutes of breakdown time was reduced. Hence, it is concluded that the downtime and production time are inversely proportional to each other. Any decrease in one of them will increase the other by the same amount of time. The bar chart in Fig. 6 shows the increase in the production (run) time of one machine up to thirty minutes.

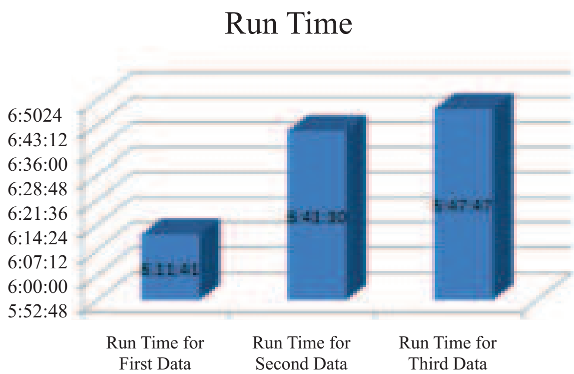

Fig. 2. Runtime for a single PW-2 Machine

The hourly production is also recorded. Fig. 7 depicts that that around 720 packets per shift for a single machine is rejected initially. After implementation of the ES and removal of the root cause, the rejections are reduced to 520 packets. The third bar in Fig. 3 shows the third reading depicting that the rejections are reduced to 480 packets. This leads to waste minimization and ultimately contribute towards the increase in production.

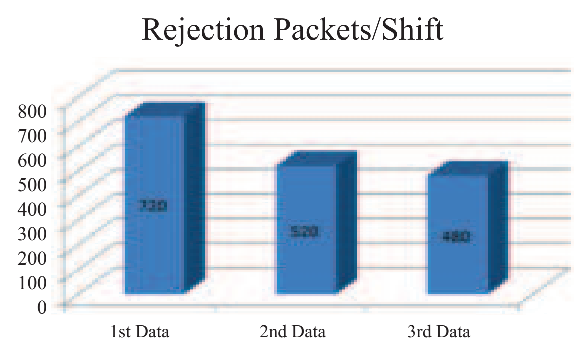

Fig. 3. Rejection of Packets per shift for single machine

The increase in uptime due to identification and subsequent removal of the root cause leads to reduction in the rejections of the packets. The production for single machine was increased over a series of readings as shown in Figure 8. A single machine production was increase from 2480 to 2720 (the increase is around 9.6 percent).

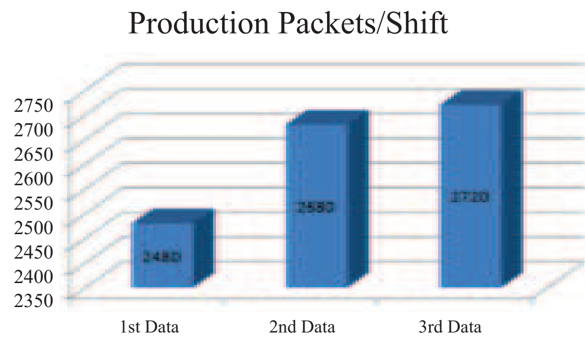

Fig. 4. Production per shift of single machine

VI. CONCLUSIONS

Maintenance is often ignored and overlooked whereas it is one of the important aspects of the overall manufacturing. It is directly related to production cost and productivity. It can rightly be termed as center theme line for a good manufacturing unit. Employing appropriate preventive and corrective maintenance measures increases the production time significantly. For a good maintenance system to be in place a continuous training program needs to be developed to properly train operators and technicians. By imparting a thorough knowledge of the breakdowns, scheduled maintenance and replacements of machine parts the breakdowns are reduced efficiently. Expert system not only helps to generate the database of all the breakdowns along with their root causes, but also guide the operator/technician to quickly search for the real root cause. It results in making informed steps to reduce the downtime on time. Managers and researchers may incorporate following recommendations for much better results. Expert system can be further extended to all the other machines available at the shop floor. Managers can deploy expert system for more accurate and precise decision-making. In addition, sensors may be integrated to automatically detect the breakdown and show the root cause. Furthermore, real time data form sensors could be used to expedite or defer (incase schedule maintenance already performed) routine maintenance. Different probabilities can be assigned to the causes of the breakdown depending on the real shop floor environment.

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